1   SPECIFICATION

2

3   REFRIGERATOR AND AIR CONDITIONER

4

5   TECHNICAL FIELD

6 [0001]

7   The present invention relates to refrigerators used in freezers, refrigerating

8 chambers, ice-makers, water-coolers, and air conditioners having cooling functions,

9 etc., and to air conditioners for cooling and warming.

10

11   BACKGROUND ART

12 [0002]

13   In conventional refrigerators and air conditioners for cooling and warming air

14 configured of compressors, radiators, flow control valves, and evaporators, which are

15 connected by coolant pipes and configured in such a way that a hydrofluorocarbon

16 coolant (hereinafter referred to as an HFC coolant) circulates, the global warming

17 potential of the HFC coolant is relatively large, which cause evil effects of the global

18 warming.

19 [0003]

20   Refrigerators and air conditioners for cooling and warming are now developed

21 using a hydrocarbon coolant (hereinafter referred to as an HC coolant) such as

22 propane, ammonia, and carbon dioxide, whose global warming potential values are

23 lower than that of chlorofluorocarbon. When the HC coolant or ammonia is used,

24 because these coolants are flammable, measures not to ignite themselves are needed;

25 therefore, the usage is limited by the law. Although carbon dioxide is nonflammable,

26 a problem is included in which the coefficient of performance (hereinafter referred to

27 as the COP) deteriorates.

28 [0004]

29   In a case of an air conditioner as an example of a refrigerator using carbon

30 dioxide as a coolant, the reason is explained why the COP deteriorates when carbon

dioxide is used as the coolant. An air conditioner has cooling/warming rate conditions that define atmospheric temperatures. In a cooling operation, when dry-bulb temperature is 35 degrees outside a room, the dry-bulb temperature is 27 degrees and wet-bulb temperature is 19 degrees inside the room. In a warming operation, when the dry-bulb temperature is 7 degrees and the wet-bulb temperature is 6 degrees outside the room, the dry-bulb temperature is 20 degrees inside the room. In a case in which carbon dioxide is used as the coolant, the COP in a cooling rate condition especially deteriorates under the outdoor temperature being relatively high. This phenomenon is caused by the coolant temperature increasing up to not lower than 35 degrees at the exit of a heat exchanger placed outside the room, because the dry-bulb temperature outside the room is 35 degrees. When carbon dioxide expands from the super critical state, a region in which the specific heat is relatively large exists in approximately from 10 to 60 degrees; however, in a state in which the dry-bulb temperature outside the room is 35 degrees, because the entire of the region in which the specific heat is relatively large cannot be used, the energy consumption efficiency decreases. On the other hand, when the HFC coolant or the HC coolant is used, heat exchange is possible in which the coolant vapor can be wholly changed into the coolant liquid under the cooling rate condition; therefore, the COP is more improved than that in the case of carbon dioxide.

[0005]

A conventional air conditioner using carbon dioxide as a coolant is disclosed, in which a coolant cooling means composed of a cooling heat-exchanger, using a low-temperature heat source including water, ice-water, and seawater, is provided, and by sequentially connecting, using coolant pipes, a compressor, a radiator, the coolant cooling means, a flow control valve, and an evaporator, the coolant is circulated. This objective is to improve the COP by decreasing, using the coolant cooling means, the coolant temperature at the entrance of the flow control valve (for example, referring to Patent Document 1).

[0006]

As a cooling means for cooling the coolant at the entrance of the flow control

valve, some power is needed as the cooling means, when water or seawater, etc. in which the power is not needed cannot be used. This power is increased corresponding to the cooling ability of the cooling means. Therefore, considering the sum of the power needed for the compressor and the cooling means that are provided in the air conditioner, overcooling causes the increase of the power needed for the cooling means; consequently, the COP deteriorates. When the cooling is insufficient, the power needed for the compressor of the air conditioner increases; as a result, the COP deteriorates.

[0007]

[Patent Document 1] Japanese Laid-Open Patent Publication 54,617/1998.

DISCLOSURE OF THE INVENTION

[0008]

Although the explanation has been made with respect to the case where the refrigerator is applied to the air conditioner, when the refrigerator is used in a freezer, a refrigerating chamber, an ice-maker, or a water-cooler, the explanation is similar to that.

An objective of the present invention is to improve the COP in a refrigerator and an air conditioner having a cooling and a warming functions in which a nonflammable coolant such as carbon dioxide is used whose global warming potential is lower than that of chlorofluorocarbon, and a cooling means is provided for cooling, using energy, the coolant at the entrance of a flow-control valve.

[0009]

A refrigerator according to the present invention includes a compressor for compressing a coolant, a radiator for radiating heat from the coolant, a coolant cooling means for cooling the coolant, a flow control valve for regulating the flow volume of the coolant, an evaporator for evaporating the coolant, and a heat-exchange-amount control means for controlling the amount of heat exchanged in the coolant cooling means, wherein the coolant is circulated through the compressor, the radiator, the coolant cooling means, the flow control valve, and the evaporator, in that sequence.

[0010]

An air conditioner according to the present invention includes a compressor for compressing a coolant, a four-way valve for switching the direction in which the coolant as outputted from the compressor flows, an outdoor heat exchanger for exchanging heat between the coolant and outdoor air, a coolant cooling/heating means for cooling as well as heating the coolant, a flow control valve for regulating the flow volume of the coolant, an indoor heat exchanger for exchanging heat between the coolant and indoor air, and a heat-exchange-amount control means for controlling the amount of heat exchanged in the coolant cooling/heating means, wherein when the air conditioner is being operated for cooling, the coolant is circulated through the compressor, the outdoor heat exchanger, the coolant cooling/heating means, the flow control valve, and the indoor heat exchanger, in that sequence, and when the air conditioner is being operated for warming, the coolant is circulated through the compressor, the indoor heat exchanger, the flow control valve, the coolant cooling/heating means, and the outdoor heat exchanger, in that sequence.

[0011]

The refrigerator according to the present invention includes the compressor for compressing the coolant, the radiator for radiating the heat from the coolant, the coolant cooling means for cooling the coolant, the flow control valve for regulating the flow volume of the coolant, the evaporator for evaporating the coolant, and the heat-exchange-amount control means for controlling the amount of the heat exchanged in the coolant cooling means, wherein the coolant is circulated through the compressor, the radiator, the coolant cooling means, the flow control valve, and the evaporator, in that sequence; therefore, the efficiency can be suitably improved.

[0012]

The air conditioner according to the present invention includes the compressor for compressing the coolant, the four-way valve for switching the direction in which the coolant as outputted from the compressor flows, the outdoor heat exchanger for exchanging the heat between the coolant and outdoor air, the coolant cooling/heating means for cooling as well as heating the coolant, the flow control valve for regulating

- 4 -

1 the flow volume of the coolant, the indoor heat exchanger for exchanging the heat

2 between the coolant and indoor air, and the heat-exchange-amount control means for

3 controlling the amount of the heat exchanged in the coolant cooling/heating means,

4 wherein when the air conditioner is being operated for cooling, the coolant is circulated

5 through the compressor, the outdoor heat exchanger, the coolant cooling/heating

6 means, the flow control valve, and the indoor heat exchanger, in that sequence, and

7 when the air conditioner is being operated for warming, the coolant is circulated

8 through the compressor, the indoor heat exchanger, the flow control valve, the coolant

9 cooling/heating means, and the outdoor heat exchanger, in that sequence; therefore,

10 the efficiency can be suitably improved.

11

12   BRIEF DESCRIPTION OF DRAWINGS

13 [0013]

14   Fig. 1 is a coolant-circuit diagram explaining a configuration of an air

15 conditioner according to Embodiment 1 of the present invention;

16   Fig. 2 is a pressure-enthalpy chart explaining the variation of coolant states in

17 the air conditioner according to Embodiment 1 of the present invention;

18   Fig. 3 is a view for explaining each position corresponding to respective coolant

19 states in the coolant-circuit diagram according to Embodiment 1 of the present

20 invention;

21   Fig. 4 represents calculation results in which the COP improvement ratios are

22 simulated under cooling rate conditions each corresponding to respective coolant

23 temperatures at the entrance of a flow control valve provided in the air conditioner

24 according to Embodiment 1 of the present invention;

25   Fig. 5 represents calculation results in which the COP improvement ratios are

26 simulated under cooling rate conditions each corresponding to respective drying ratios

27 that are ratios of coolant drying rates at the entrance of an evaporator and drying

28 rates at the exit of a radiator, when the coolant is decompressed up to the coolant

29 evaporation temperature, that are provided in the air conditioner according to

30 Embodiment 1 of the present invention;

Fig. 6 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 2 of the present invention;

Fig. 7 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 3 of the present invention;

Fig. 8 is a pressure-enthalpy chart explaining, when the air conditioner is being operated for cooling, the variation of coolant states in the air conditioner according to Embodiment 3 of the present invention;

Fig. 9 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 4 of the present invention;

Fig. 10 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 5 of the present invention;

Fig. 11 is a view for explaining parameters used in a process in which drying ratios are estimated in Embodiment 5 of the present invention;

Fig. 12 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 6 of the present invention;

Fig. 13 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 7 of the present invention;

Fig. 14 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 8 of the present invention;

Fig. 15 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 9 of the present invention;

Fig. 16 is a pressure-enthalpy chart explaining the efficiency improvement by the configuration of the air conditioner according to Embodiment 9 of the present invention;

Fig. 17 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 10 of the present invention;

Fig. 18 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 11 of the present invention;

Fig. 19 is a pressure-enthalpy chart explaining the efficiency improvement by the configuration of the air conditioner according to Embodiment 11 of the present

invention;

Fig. 20 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 12 of the present invention;

Fig. 21 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 13 of the present invention;

Fig. 22 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 14 of the present invention;

Fig. 23 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 15 of the present invention;

Fig. 24 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 16 of the present invention; and

Fig. 25 is a coolant-circuit diagram explaining a configuration of an air conditioner according to Embodiment 17 of the present invention.

EXPLANATION OF SYMBOLS

[0014]

1: Air conditioner

2: Compressor

2A: Intermediary pressure inlet

3: Radiator

4: Flow control valve

5: Evaporator

6: Coolant pipe

6A: Coolant pipe

6B: Coolant pipe

10: Second compressor

11: Condenser

12: Second flow control valve

13: Second evaporator

14: Second coolant pipe

1 15: Coolant cooler (Coolant cooling means)

2 16: Heat-exchanging controller (Heat-exchanging controlling means)

3 16A: Drying-ratio estimation unit (Drying-ratio estimating means)

4 16B: Drying-ratio control-range determination unit (Drying-ratio control-range

5 determining means)

6 16C: Coolant flow controller (Controlling means)

7 16D: Flow-control-valve-entrance-temperature control-range determination unit

8 (Flow-control-valve-entrance-temperature   estimating   means,

9 Flow-control-valve-entrance-temperature control-range determining means)

10 20: Four-way valve

11 21: Outdoor heat exchanger

12 22: Indoor heat exchanger

13 23: First heat exchanger

14 24: Second heat exchanger

15 25: Coolant cooling/heating unit

16 40: Second four-way valve

17 41: First heat exchanger

18 42: Second heat exchanger

19 45: Gas-liquid separator

20 46: Third flow control valve

21 47: Bypass pipe

22 50: Third radiator

23 51: Third compressor

24 52: Flow-route switching valve (Flow-route switching means)

25 60: Third heat exchanger

26 70: Second bypass pipe

27 71: Forth flow control valve

28 P1: Pressure gauge (First pressure measuring means)

29 P2: Pressure gauge (Second pressure measuring means)

30 T1: Thermometer (First temperature measuring means)

1   T2: Thermometer (Second temperature measuring means)

2   T3: Thermometer (Third temperature measuring means)

3   T4: Thermometer (Forth temperature measuring means)

4   T5: Thermometer (Fifth temperature measuring means)

5

6   BEST MODE FOR CARRYING OUT THE INVENTION

7   [0015]

8   Embodiment 1.

9   Embodiment 1 according to the present invention is explained using Fig. 1 -

10 Fig. 5.   Fig. 1 is a coolant-circuit diagram explaining a configuration of a cooling only

11 air conditioner according to Embodiment 1.   Fig. 2 is a pressure-enthalpy chart

12 explaining the variation of coolant states.   In Fig. 3, each position corresponding to

13 respective coolant states in the coolant-circuit diagram is explained.   Fig. 4 represents

14 calculation results in which the COP improvement ratios are simulated under cooling

15 rate conditions each corresponding to respective coolant temperatures at the entrance

16 of a flow control valve 4.   Fig. 5 represents calculation results in which the COP

17 improvement ratios are simulated under the cooling rate condition in response to

18 respective drying ratios that are ratios of coolant drying rates at the entrance of an

19 evaporator 5 and drying rates at the exit of a radiator 3 when the coolant is

20 decompressed up to the coolant evaporation temperature.

21 [0016]

22   In Fig. 1, an air conditioner 1 is composed of a compressor 2 for compressing

23 coolant, a radiator 3 for radiating heat from the coolant, a coolant cooler 15 that is a

24 coolant cooling means for cooling the coolant, a flow control valve 4 for controlling the

25 coolant flow, and an evaporator 5 for evaporating the coolant, which are sequentially

26 connected by coolant pipes 6, and is configured in such a way that carbon dioxide as

27 the coolant circulates.   In the figure, the coolant flow is represented by arrows.   A

28 heat exchanging controller 16 is also provided as a heat-exchanging control means for

29 controlling the heat-exchanging amount in the coolant cooler 15.   The coolant that

30 circulates in a vapor-compression refrigeration cycle configured of the compressor 2,

1 etc. is also referred to as a first coolant.

2 [0017]

3 The coolant cooler 15 operates in which propane, as a second coolant, whose

4 energy consumption efficiency is higher than that of carbon dioxide, circulates in a

5 vapor-compression refrigeration cycle. In the coolant cooler 15, a second compressor

6 10 for compressing the second coolant, a condenser 11 for radiating the heat from the

7 second coolant, a second flow control valve 12 for controlling the second coolant flow,

8 and a second evaporator 13 for evaporating the second coolant using the coolant heat

9 at the entrance of the flow control valve 4 provided in a coolant circulating route are

10 sequentially connected by a second coolant pipes 14. In the figure, the second coolant

11 flow is also represented by arrows.

12 It is assumed that the cooling ability of the coolant cooler 15 according to the

13 refrigeration cycle using the second coolant is set at approximately from one-tenth to

14 one-fifth of that using the first coolant.

15 [0018]

16 The evaporator 5 is placed inside a room in which air is to be cooled,

17 meanwhile the other units are placed outside the room; then, the coolant pipes 6 are

18 laid so that the coolant circulates among the units. Here, the evaporator 3 may also

19 be placed outdoors, for example, in a railway platform. Regarding the units other

20 than the radiator 3, the evaporator 5, and the condenser 11 that are needed to

21 heat-exchange with air, necessary and sufficient heat insulation is maintained so that

22 the efficiency does not decrease due to heat leakage.

23 [0019]

24 Next, variation of coolant states (exactly, first-coolant states) is explained

25 according to Fig. 2. In the figure, regarding points, such as the point "C", which are

26 not located on the corners of a locus representing the coolant states, their positions are

27 represented by black circles. First, low-temperature low-pressure coolant vapor in

28 the coolant pipe 6 connected to the inlet of the compressor 2 positions at the point "A"

29 in Fig. 2. Although the entire of the coolant at the entrance of the compressor is

30 needed to be vapor, because the higher the temperature of the coolant vapor the more

1 the mechanical input power becomes needed, the overheat rate at the point "A" is set

2 at a predetermined value close to nil.

3 When the coolant is compressed by the compressor 2, the coolant is changed to

4 high-temperature high-pressure super-critical fluid as represented by the point "B",

5 and then outputted. The coolant is sent into the radiator 3; then, the temperature of

6 the coolant decreases after heat exchange is performed there with air, etc., and the

7 coolant becomes a state of high-pressure super-critical fluid as represented by the

8 point "C".

9 The coolant is further cooled by the coolant cooler 15 whose cooling ability is

10 controlled by the heat exchanging controller 16, and the temperature of the coolant

11 decreases; then, the coolant becomes a state as represented by the point "D".

12 Moreover, the coolant flows into the flow control valve 4, and is decompressed therein;

13 then, the coolant changes to a low-temperature low-pressure gas-liquid two-phase

14 state as represented by the point "E". The coolant is sent into the evaporator 5,

15 evaporates there after heat exchange is performed with air, etc., and becomes

16 low-temperature low-pressure coolant vapor as represented by the point "A"; then, the

17 coolant is returned back to the compressor.

18 [0020]

19 When the coolant cooler 15 does not cool the coolant, the coolant as

20 represented by the point "C" in Fig. 2 is flowed into the flow control valve 4 and

21 decompressed; then, the coolant changes to the low-temperature low-pressure

22 gas-liquid two-phase state as represented by the point "F". A locus of the coolant

23 state in which the coolant cooler 15 does not cool the coolant is represented by a

24 broken line. Comparing the locus "A - B - C- D - E - A" when the coolant cooler 15

25 cools the coolant and the locus "A - B - C - F - A" when the coolant cooler 15 does not

26 cool the coolant, the difference is as follows. Because the enthalpy difference during

27 the locus "A - B" is H1, the mechanical input power in the compressor is the same in

28 both cases. Regarding the cooling ability, when the coolant cooler 15 cools the coolant,

29 the enthalpy difference during the locus "E - A" is H2A, meanwhile when the coolant

30 cooler 15 does not cool the coolant, the enthalpy difference during the locus "F - A" is

1   H2B. H2A is larger than H2B as obviously represented in Fig. 2; therefore, if the

2   mechanical input power in the coolant cooler 15 is not considered, the more cooling the

3   coolant, the more the COP is improved.

4   [0021]

5   Actually, because the mechanical input power is also needed in the coolant

6   cooler 15, in a range in which the value of the ratio between improved cooling ability

7   due to the coolant being cooled in the coolant cooler 15 and mechanical input power

8   into the coolant cooler 15 is larger than the COP, the more cooling the coolant, the

9   more the COP is improved; meanwhile, if the value of the ratio becomes smaller than

10   the COP value, the COP deteriorates.   Thereby, regarding the heat exchange amount,

11   that is, the cooling amount in the coolant cooler 15, the most suitable value for most

12   improving the COP is to exist.

13   [0022]

14   This fact is more quantitatively explained. Fig. 4 is views representing

15   calculation results in which the COP improvement ratios are simulated under cooling

16   rate conditions each corresponding to each coolant temperature at the entrance of the

17   flow control valve 4.   Fig. 5 is views representing calculation results in which the COP

18   improvement ratios are simulated under cooling rate conditions each corresponding to

19   each drying ratio, on the horizontal axis, which is a ratio of a coolant drying rate at the

20   entrance of the evaporator 5 and a drying rate at the exit of the radiator 3 when the

21   coolant is decompressed up to the coolant evaporation temperature.   The numerator

22   of the drying ratio is the drying rate at the point "E" in Fig. 2, while the denominator

23   is the drying rate at the point "F" in Fig. 2.   Here, the drying rate is the ratio of a

24   coolant-vapor component to the coolant in a gas-liquid two-phase state.   When only

25   the coolant vapor exists, the drying rate is "1.0"; while when the coolant vapor does not

26   exist, the drying rate is "0.0".

27   [0023]

28   Detailed conditions for the simulation are as follows.   In a cooling rate

29   condition, the coolant is carbon dioxide, the efficiency of the compressor 2 is 70%, the

30   inlet-vapor overheat rate of the compressor 2 is 0 degree, the temperature difference

1 between the coolant and air at the exit of the radiator 3 is 3 degrees, the second

2 coolant used in the coolant cooler 15 is propane, the efficiency of the second compressor

3 10 is 70%, and the condensation temperature in the condenser 11 is 40 degrees.

4   In Fig. 4, when coolant pressure Pd after compressed by the compressor 2 is

5 assumed that Pd is any one of 9 MPa, 10 MPa and 11 MPa, and coolant temperature

6 Te at the entrance of the evaporator 5 is assumed that Te is any one of 15 degrees, 10

7 degrees, 5 degrees, and 0 degree, COP improvement ratios are represented, which are

8 values obtained by which COP values when coolant temperature Tf at the entrance of

9 the flow control valve 4 is varied are divided by COP values when, assuming that Te is

10 0 degree, the coolant is not cooled by the coolant cooler 15, that is, Tf is 38 degrees.

11   In Fig. 5, when Pd and Te are assumed to be similar to those in Fig. 4, COP

12 improvement ratios are represented, which are values obtained by which COP values

13 when the drying ratio (represented by the parameter X) is varied are divided by COP

14 values when, assuming that Te is 0 degree, the coolant is not cooled by the coolant

15 cooler 15, that is, X is 1.0.

16 [0024]

17   Fig 4 and Fig. 5 represent that, when the coolant temperature Tf at the

18 entrance of the flow control valve 4 is suitably controlled, the COP is improved

19 approximately 1.3 - 1.4 times compared with a case in which the coolant is not cooled

20 at all. Moreover, in Fig. 4, when Te is 15 degrees or 10 degrees, in a range in which Tf

21 is 20 - 30 degrees in any case when Pd is 9 MPa, 10 MPa or 11 MPa, each COP

22 includes a maximum value, and its variation width is narrower than 0.1. When Te is

23 5 degrees or 0 degree, in a range in which Tf is 15 - 25 degrees in any case when Pd is

24 9 MPa, 10 MPa or 11 MPa, each COP includes a maximum value, and its varying

25 width is narrower than 0.1. Fig. 5 represents that, except for a case in which Pd is 11

26 Pa and Te is 15 degrees, in a range in which the drying ratio X is 0.2 - 0.5, each COP

27 includes a maximum value, and its varying width is narrower than 0.1. In the case

28 in which Pd is 11 Pa and Te is 15 degrees, when X is nearly equal to 0.1, the COP

29 takes the maximum value, and also in a range in which X is 0.2 - 0.5, the difference

30 from the maximum value is only approximately 0.2.

[0025]

In Embodiment 1 according to the present invention, the heat-exchanging amount in the coolant cooling means is controlled by the heat-exchanging control means so that, in a given operating condition, the difference from the maximum value of the COP is within a relatively small predetermined value; thus, the coolant temperature at the entrance of the flow control valve 4 is suitably controlled. By providing the heat-exchanging control means, deterioration in the COP due to the heat-exchanging amount in the coolant cooling means being insufficient or excessive can be prevented. That is, it is surely effective to improve the COP. Moreover, the improved COP value can be set at a value close to that obtained when a coolant such as propane used as the second coolant is used. The second coolant is flammable, or its global warming potential is inferior to that of the first coolant. It is also effective to reduce such second-coolant usage. Furthermore, the coolant circuit of the second coolant can be configured by a closed loop outside a room; thereby, leakage of the second coolant inside the room can be prevented.

[0026]

Here, in Fig. 4 and Fig. 5, graphs are drawn assuming that Pd and Te are constant; however, when the heat-exchanging amount is varied in the coolant cooling means, a case also appears in which Pd and Te vary a little bit. Even in such a case, because the heat-exchanging amount can be realized by the coolant cooling means, in which the COP value reaches the maximum in response to the variation of the heat-exchanging amount in the coolant cooling means, if the heat-exchanging amount is controlled in the coolant cooling means so that the COP reaches a value in a predetermined range close to the maximum, the COP can surely be improved.

[0027]

In this Embodiment 1, although carbon dioxide has been used as the first coolant, only if the coolant, whose global warming potential is lower than that of chlorofluorocarbon, is nonflammable, a coolant other than the carbon-dioxide one may be used. Although propane has been used as the second coolant, only if a coolant has better energy consumption efficiency than that of the first coolant, the coolant, which

1   is flammable, and whose global warming potential is higher than that of the first

2   coolant, may be used.

3   As the second coolant, usage of, for example, HFC coolant, HC coolant, and

4   ammonia can be considered.   As the coolant cooling means, although the

5   vapor-compression refrigeration cycle using the second coolant is used, an adsorption

6   refrigeration cycle or a means using the Peltier effect, etc. may also be used.   In a case

7   in which a low-temperature heat source composed of water, ice-water, and seawater

8   can be used, a coolant cooling means may be used in which, after the cooling using the

9   low-temperature heat source has been performed, the cooling corresponding to the

10   shortage of the cooling amount is performed by a means that consumes energy.

11   In a case in which the vapor-compression refrigeration cycle using the second

12   coolant is not utilized, when HFC coolant, HC coolant, or ammonia, etc. is also used as

13   the first coolant, by controlling the heat-exchanging amount in the coolant cooling

14   means using the heat-exchanging controlling means, an effect can be obtained in

15   which the COP can surely be improved.   Although a single compressor has been used,

16   the present invention can also be applied to a case in which two or more than two

17   compressors are used.   Although a single second-compressor has been used, the

18   present invention can also be applied to a case in which two or more than two

19   second-compressors are used.

20   [0028]

21   Although a case in which a refrigerator is used in a cooling only air conditioner

22   has been explained, the refrigerator may be configured to be used in an air conditioner

23   having both cooling and warming functions, a freezer, a refrigerating chamber, an

24   ice-maker, or a water-cooler, etc.   As an unnecessary addition, a refrigerator or a

25   cooler means an apparatus that produce a low-temperature atmosphere, and does not

26   mean only an apparatus in which food, etc. is frozen and stored at low temperature.

27   Moreover, an air conditioner having both cooling and warming functions is also

28   included in a refrigerator during a cooling operation.   The above is also applied to the

29   other embodiments.

30

1   [0029]

2   Embodiment 2.

3   In Fig. 6, a coolant-circuit diagram is illustrated for explaining a configuration

4   of an air conditioner having cooling and warming functions according to Embodiment

5   2 of the present invention.   In the figure, coolant flow during a cooling operation is

6   represented by solid-line arrows, meanwhile coolant flow during a warming operation

7   is represented by broken-line arrows.

8   Only different elements from those in Fig. 1 according to Embodiment 1 that

9   represents a case in which only cooling is performed are explained.   A four-way valve

10   20 for switching the flowing directions of the coolant outputted from the compressor 2

11   is additionally provided, so as to enable both cooling and warming operations.

12   Because, during the warming operation, the radiator 3 and the evaporator 5 operate

13   with their roles being exchanged each other in response to the case of the cooling

14   operation, the radiator 3 is replaced by an outdoor heat exchanger 21 for exchanging

15   heat between the coolant and the outdoor air, and the evaporator 5 is replaced by an

16   indoor heat exchanger 22 for exchanging heat between the coolant and the indoor air.

17   Here, during a cooling operation, the outdoor heat exchanger 21 operates similarly to

18   the radiator 3, meanwhile the indoor heat exchanger 22 operates similarly to the

19   evaporator 5.

20   By the four-way valve 20, during the cooling operation, the coolant circulates

21   through the compressor 2, the outdoor heat exchanger 21, the coolant cooler 15, the

22   flow control valve 4, and the indoor heat exchanger 22, in that sequence.   During the

23   warming operation, the coolant circulates through the compressor 2, the indoor heat

24   exchanger 22, the flow control valve 4, the coolant cooler 15, and the outdoor heat

25   exchanger 21, in that sequence.   The other elements are configured similar to those in

26   Embodiment 1.

27   [0030]

28   Next, an operation is explained.   First, the radiator 3 and the evaporator 5

29   are replaced by the outdoor heat exchanger 21 and the indoor heat exchanger 22,

30   respectively; however, the operation during the cooling operation is similar to that in

Embodiment 1. A pressure-enthalpy chart explaining the variation of the coolant states also becomes similar to that represented in Fig. 2.

Next, the operation during the warming operation is explained. First, low-temperature low-pressure coolant vapor in the coolant pipe 6 connected to the inlet of the compressor 2 is positioned at the point "A", in Fig. 2, in which the entire coolant is vapor, and the overheat rate drops to a predetermined value close to nil. After compressed by the compressor 2, the coolant is changed to high-temperature high-pressure super-critical fluid as represented by the point "B", and then, outputted. The outputted coolant is sent through the four-way valve 20 into the indoor heat exchanger 22 as a radiator, and changed to high-pressure super-critical fluid represented by the point "C" after its temperature decreases due to heat exchange so as to warm indoor air. Here, rigorously, the point "C" positions at a point in which the enthalpy is lower than in the case of the cooling operation. The reason is because the indoor temperature during the warming rated operation is 20 degrees, and the temperature is lower than the outdoor temperature of 35 degrees during the cooling rated operation.

[0031]

The coolant flows into the flow control valve 4, and decompressed there; then, the coolant changes to a low-temperature low-pressure gas-liquid two-phase state represented by the point "F". Because the coolant cooler 15 is not operated during the warming operation, even if the coolant passes through the second evaporator 13 in the coolant cooler 15, the coolant state little changes. Although it is rigorously possible that heat exchange in the second evaporator 13 is performed between the coolant and the second coolant, the heat-exchanging amount is so little as to be negligible. The reason is because the second coolant does not circulate due to stopping of the second compressor 10, calories are difficult to conduct through a thin and long shaped coolant in the coolant pipe due to the thin coolant pipe, and the coolant cooler 15 neither releases nor absorbs calories due to the entire of the coolant cooler 15 being thermally insulated. Also in the other heat exchangers, when at least one of the coolant and the second coolant does not flow, it is assumed that heat is not

1   exchanged.

2   The coolant is sent into the outdoor heat exchanger 21 as an evaporator,

3   evaporates there after being heat-exchanged with air, etc., and changes to

4   low-temperature low-pressure coolant vapor represented by the point "A". Then, the

5   coolant is returned to the compressor 1 through the four-way valve 20. Compiling the

6   above, the coolant-state varying locus during the warming operation becomes the locus

7   "A - B - C - F - A" in Fig. 2.

8   Because the coolant cooler 15 stops during the warming operation, the COP

9   value becomes the same as that of a case in which the coolant cooler 15 is not provided.

10   [0032]

11   Also in the configuration of this Embodiment 2, it is effective that the COP can

12   surely be improved, using the heat-exchanging control means, by suitably controlling

13   the heat-exchanging amount in the coolant cooling means during the cooling operation.

14   It is also effective that, even if usage of the second coolant that is flammable or its

15   global warming potential is inferior to that of the first coolant is decreased, the COP

16   equivalent to that of a case in which only the second coolant is used can be realized.

17   Moreover, the coolant circuit of the second coolant can be configured by a closed loop

18   outside a room; thereby, leakage of the second coolant inside the room can be

19   prevented.

20

21   [0033]

22   Embodiment 3.

23   Fig. 7 is a coolant-circuit diagram illustrating a configuration of an air

24   conditioner according to Embodiment 3. In Embodiment 3, the coolant cooler 15 in

25   Embodiment 2 is changed to a coolant cooling/heating unit 25 as a coolant

26   cooling/heating means for cooling or heating the coolant.

27   Only different elements from those in Embodiment 2 are explained. In the

28   coolant cooling/heating unit 25, a second four-way valve 40 for switching the flowing

29   directions of the second coolant outputted from the second compressor is additionally

30   provided, the condenser 11 is replaced by a first heat exchanger 41 for exchanging heat

1 between the second coolant and the outdoor air, and the second evaporator 13 is

2 replaced by a second heat exchanger 42 for exchanging heat between the coolant and

3 the second coolant so as to cool or heat the coolant. Here, during a cooling operation,

4 the first heat exchanger 41 operates similar to the condenser 11, meanwhile the

5 second heat exchanger 42 operates similar to the second evaporator 13.

6 By the second four-way valve 40, during a cooling operation, the coolant

7 circulates through the second compressor 10, the first heat exchanger 41, the second

8 flow control valve 12, and the second heat exchanger 42, in that order. During a

9 warming operation, the coolant circulates through the compressor 2, the second heat

10 exchanger 42, the second flow control valve 12, and the first heat exchanger 41, in that

11 order. The other elements are configured similar to those in Embodiment 2.

12 [0034]

13 Next, an operation is explained. The operation during a cooling operation is

14 similar to that of the cases in Embodiment 1 and Embodiment 2. During a warming

15 operation, although the coolant cooler 15 has stopped in Embodiment 2, in this

16 Embodiment 3, the coolant cooling/heating unit 25 operates so as to heat the coolant.

17 A pressure-enthalpy chart explaining the variation of coolant states, during the

18 warming operation, in the air conditioner according to Embodiment 3 of the present

19 invention is illustrated in Fig. 8. Solid lines represent the case of this Embodiment 3,

20 while broken lines represent the case of Embodiment 2.

21 [0035]

22 The operation during the warming operation becomes as follows. First, the

23 low-temperature low-pressure coolant vapor in the coolant pipe 6 connected to the

24 inlet of the compressor 2 positions at the point "A2", in Fig. 8, in which the entire

25 coolant is vapor, and the overheat rate drops to a predetermined value close to nil. At

26 the point "A2", the pressure is a little higher, while the enthalpy is a little lower than

27 those at the point "A" according to Embodiment 2, and the reason will be explained

28 later. The coolant is compressed by the compressor 2, and then, outputted in a state

29 of high-temperature high-pressure super-critical fluid represented by the point "B2".

30 The pressures at the point "B2" and the point "B" are equivalent, meanwhile the

1   enthalpy at the point "B2" is lower than that at the point "B".

2   The outputted coolant is sent through the four-way valve 20 into the indoor

3   heat exchanger 22 as a radiator, and changed to the high-pressure super-critical fluid

4   represented by the point "C" after its temperature is decreased by the heat exchanged

5   so as to warm indoor air.   Because, in the indoor heat exchanger 22, the heat

6   exchange is performed between the coolant and the indoor air set at a given condition,

7   the point "C" positions at approximately the same position as that in Embodiment 2.

8   The coolant flows into the flow control valve 4, and changes there to a

9   low-temperature low-pressure gas-liquid two-phase state represented by the point

10 "F2".   At the point "F2", the pressure is the same as that at the point "A2", and a little

11 higher than that at the point "F".   The coolant is heated by the second heat exchanger

12 41 in the coolant cooling/heating unit 25, and changed to a state represented by the

13 point "G" as a gas-liquid two-phase state in which coolant vapor increases.   The

14 coolant is sent to the outdoor heat exchanger 21 as an evaporator, evaporated there

15 after heat being exchanged with air, etc., changed to low-temperature low-pressure

16 coolant vapor, and returned to the compressor through the four-way valve 20.

17 [0036]

18   Here, the reason is explained, why the coolant pressure outputted from the

19 flow control valve 4, by heating the coolant using the second heat exchanger 41 in the

20 coolant cooling-heating unit 25, becomes higher than that of a case in which the

21 coolant is not heated.   By heating the coolant, calories to be absorbed in the outdoor

22 heat exchanger 21 has decreased; thereby, the ability of the outdoor heat exchanger 21

23 has relatively increased.   When the ability of the outdoor heat exchanger 21 increases,

24 the difference between the coolant-vapor temperature and a given outdoor

25 temperature decreases, that is, the evaporation temperature increases.   When the

26 evaporation temperature increases, the coolant-vapor pressure also increases.

27 [0037]

28   Next, it is explained that, by heating the coolant using the second heat

29 exchanger 41 in the coolant cooling/heating unit 25, the COP is improved.   The COP

30 is assumed to be given by COP1 when the coolant is not heated, and given by COP2

1 when the coolant is heated. Moreover, the enthalpy difference between those at the

2 points "B" and "A" is assumed to be given by $\Delta H1$, meanwhile the enthalpy difference

3 between those at the points "B2" and "A2" is assumed to be given by $\Delta H2$. The

4 enthalpy difference between those at the points "A" and "C" is assumed to be given by

5 $\Delta H3$, meanwhile the enthalpy difference between those at the points "A2" and "C" is

6 assumed to be given by $\Delta H4$. Here, $\Delta H1$ is mechanical input of the compressor 2

7 when the coolant is not heated in the coolant cooling/heating unit 25, meanwhile $\Delta H2$

8 is mechanical input of the compressor 2 when the coolant is heated. Moreover,

9 assuming the efficiency of the outdoor heat exchanger 22 is 100%, $\Delta H1 + \Delta H3$ becomes

10 calories obtained by the indoor heat exchanger 21 when the coolant is not heated,

11 meanwhile $\Delta H2 + \Delta H4$ becomes calories obtained by the indoor heat exchanger 21

12 when the coolant is heated. Therefore, according to the parameter definition the

13 following equations are established.

14

15 $\qquad COP1 = (\Delta H1 + \Delta H3) / \Delta H1 \qquad (Eq.\ 1)$

16 $\qquad COP2 = (\Delta H2 + \Delta H4) / \Delta H2 \qquad (Eq.\ 2)$

17 $\qquad COP2 - COP1 = (\Delta H2 + \Delta H4) / \Delta H2 - (\Delta H1 + \Delta H3) / \Delta H1$

18 $\qquad\qquad\qquad = \Delta H4 / \Delta H2 - \Delta H3 / \Delta H1 \qquad (Eq.\ 3)$

19

20 As found in Fig. 8, $\Delta H3$ is nearly equal to $\Delta H4$. When this result is substituted into

21 Eq. 3, the following equation is obtained.

22

23 $\qquad COP2 - COP1 \cong (\Delta H3 \times (\Delta H1 - \Delta H2)) / (\Delta H1 \times \Delta H2) \qquad (Eq.\ 4)$

24

25 [0038]

26 $\qquad$ As found in Fig. 8, because $\Delta H1$ is larger than $\Delta H2$, the right side of Eq. 4

27 always becomes positive; therefore, the COP is found to be improved by the coolant

28 being heated. The reason why $\Delta H1$ is larger than $\Delta H2$ is explained. First, after the

29 compression is performed at the point "A", a point at which the pressure becomes the

30 same as that at the point "A2" is assumed to be the point "A3". $\Delta H1$ is divided into

- 21 -

1 mechanical input (referred to as ΔH1A) needed for compressing the coolant from the

2 point "A" to the point "A3" and mechanical input (referred to as ΔH1B) needed for

3 compressing it from the point "A3" to the point "B". From the parameter definition,

4 ΔH1 is ΔH1A + ΔH1B. Generally, even if the pressures before and after compression

5 are the same, the larger the enthalpy before compression, the more the mechanical

6 input needed for compressing the coolant increases. Here, the enthalpy at the point

7 "A3" is larger than that at the point "A2". Therefore, ΔH1B is larger than ΔH2.

8 Moreover, because ΔH1A is larger than zero, ΔH1 is larger than ΔH2.

9 [0039]

10 The temperature difference between those of outdoor air and the coolant vapor

11 is essentially several degrees; therefore, the effect has the upper limit, in which the

12 temperature difference is reduced due to the heating amount being increased using

13 the second heat exchanger 41 in the coolant cooling/heating unit 25. The mechanical

14 input needed for increasing the heating amount using the second heat exchanger 41 in

15 the coolant cooling/heating unit 25 increases higher than the linear correlation

16 corresponding to the heating amount. Thereby, when the heating amount increases,

17 the COP deteriorates. An improvement effect of the COP during the warming

18 operation is less than that during the cooling operation. The capacity of the cooling

19 cycle in which the second coolant is used is approximately from one-tenth to one-fifth

20 of the first-coolant cooling cycle; although quantitative data is not represented, in an

21 operational condition in which the cooling cycle using the second coolant effectively

22 operates, the COP falls close to the maximum value.

23 [0040]

24 In the configuration of this Embodiment 3, it is also effective that, by suitably

25 controlling the heat-exchanging amount in the coolant cooling/heating means, during

26 the cooling operation, using the heat-exchanging control means, the COP can surely be

27 improved. It is also effective that, even if usage of the second coolant that is

28 flammable or its global warming potential is inferior to that of the first coolant is

29 decreased, the COP equivalent to that of a case in which only the second coolant is

30 used can be realized. Moreover, the coolant circuit of the second coolant can be

1 configured by a closed loop outside a room; thereby, leakage of the second coolant

2 inside the room can be prevented.

3 Furthermore, it is also effective that the COP during the warming operation

4 can be improved.

5

6 [0041]

7 Embodiment 4.

8 Fig. 9 is a coolant-circuit diagram illustrating a configuration of an air

9 conditioner according to Embodiment 4. In Embodiment 4, Embodiment 1 is

10 modified so that the flow volume of the coolant vapor flowing into the evaporator 5 is

11 decreased. Only different elements comparing with those in Fig. 1 according to

12 Embodiment 1 are explained. In Fig. 9, a gas-liquid separator 45 and a third flow

13 control valve 46 are provided on the route from the flow control valve 4 to the

14 evaporator 5, and a bypass pipe 47 is provided for inputting into the compressor 2 part

15 or all of the coolant vapor separated by the gas-liquid separator 45. The compressor 2

16 has an intermediary-pressure inlet 2A for drawing in the coolant during compressing.

17 The other elements are configured similarly to those in Embodiment 1.

18 [0042]

19 Next, coolant flow is explained using Fig. 9. Regarding the gas-liquid

20 two-phase-state coolant decompressed by the flow control valve 4, part or all of the

21 coolant vapor is separated by the gas-liquid separator 45, passes through the coolant

22 circuit constituted by the bypass pipe 47, is inhaled into the intermediary-pressure

23 inlet 2A of the compressor 2, and is mixed with the coolant inside the compressor 2.

24 The other coolant flow is similar to that in Embodiment 1.

25 [0043]

26 In the configuration of this Embodiment 4, it is also effective that, by suitably

27 controlling the heat-exchanging amount in the coolant cooling means using the

28 heat-exchanging control means, the COP can surely be improved. Here, regarding

29 the variation of the COP corresponding to the variation of the temperature at the

30 entrance of the flow control valve and the variation of the drying ratio, etc., the

1 tendencies are similar to those in Embodiment 1; however, because the configuration

2 of the coolant circuit is differed from that in Embodiment 1, actual values are different

3 from those represented in Fig. 4 or Fig. 5. These facts are also applied to the other

4 embodiments in which the configurations are differed from each other. It is also

5 effective that, even if usage of the second coolant that is flammable or its global

6 warming potential is inferior to that of the first coolant is decreased, the COP

7 equivalent to that of a case in which only the second coolant is used can be realized.

8 Moreover, the coolant circuit of the second coolant can be configured by a closed loop

9 outside a room; thereby, leakage of the second coolant inside the room can be

10 prevented.

11 [0044]

12 According to this configuration, because the coolant inside the compressor 2

13 can be cooled, the power needed for compressing can be reduced. Moreover, because

14 coolant vapor flow flowing through the evaporator 5 is relatively less, the coolant

15 pressure loss in the evaporator can be reduced. Accordingly, in the air conditioner

16 using the first coolant, the efficiency can be further improved. Instead of the

17 compressor 2 having the intermediary-pressure inlet 2A, double compressors may be

18 used by connecting them in series so that the bypass pipe 47 is connected to the

19 coolant pipe 6 connected at the inlet of the high-pressure-side compressor.

20 [0045]

21 Here, in this Embodiment 4, although a case in which the configuration is

22 applied to that in Embodiment 1 has been explained, in a case in which the

23 configuration is applied to Embodiment 2 or Embodiment 3, an effect similar to that

24 can also be obtained.

25

26 [0046]

27 Embodiment 5.

28 Fig. 10 is a coolant-circuit diagram illustrating a configuration of an air

29 conditioner according to Embodiment 5. In Embodiment 5, Embodiment 1 is

30 modified so that a specific means for controlling the drying ratio is provided in the

1 heat exchanging controller 16. Only different elements comparing with those in Fig.

2 1 according to Embodiment 1 are explained.

3 [0047]

4 In Fig. 10, a pressure gauge P1 as a first pressure measurement means

5 provided at the exit of the flow control valve 4, a pressure gauge P2 as a second

6 pressure measurement means provided at the entrance of the flow control valve 4, a

7 thermometer T2 as a second temperature measurement means provided at the

8 entrance of the flow control valve 4, and a thermometer T3 as a third temperature

9 measurement means provided at the exit of the radiator 3 are additionally provided.

10 Moreover, the heat exchanging controller 16 is configured of a drying-ratio estimation

11 unit 16A as a drying-ratio estimation means for estimating the drying ratio based on

12 the measurement values inputted by the pressure gauge P1, the pressure gauge P2,

13 the thermometer T2, and the thermometer T3, as the given sensors, a drying-ratio

14 control-range determination unit 16B as a drying-ratio control-range determination

15 means for obtaining a control range of the drying ratio in which the difference between

16 each COP when the drying ratio is varied and the maximum value of the COP is

17 within a predetermined range, and a coolant flow controller 16C as a control means for

18 controlling the coolant flow so that the drying ratio is within the control range

19 obtained by the drying-ratio control-range determination unit 16B. The coolant flow

20 controller 16C can control an operational frequency of the second compressor 10 and a

21 command value of the second flow control valve 12.

22 The other configurations are similar to those of the case in Embodiment 1.

23 [0048]

24 Next, an operation is explained. The coolant flow is similar to that of the case

25 in Embodiment 1. Here, an operation of the heat exchanging controller 16 is

26 explained. The drying-ratio estimation unit 16A estimates as below a drying ratio

27 from each measurement value by the pressure gauge P1, the pressure gauge P2, the

28 thermometer T2, and the thermometer T3. A diagram for explaining parameters

29 used in a process is illustrated in Fig. 11, in which drying ratios are estimated.

30 [0049]

1   The parameter definitions for explaining coolant states are represented, also

2 including the above defined ones, as follows.

3 (Parameter definitions for explaining coolant states)

4 Pd: Radiation pressure.   Measured by pressure gauge P2.

5 Td: Coolant temperature at exit of radiator 3.   Measured by thermometer T3.

6 Tf: Coolant temperature at entrance of flow control valve 4.   Measured by

7 thermometer T2.

8 Pe: Coolant pressure at exit of flow control valve 4.   Measured by pressure gauge P1.

9 Te: Evaporation temperature.   Obtained from Pe and saturation vapor pressure of

10 coolant.

11 hd: Coolant enthalpy at exit of radiator 3.

12 hf: Coolant enthalpy at entrance of flow control valve 4.

13 heL: Coolant saturated liquid enthalpy at pressure Pe.

14 heG: Coolant saturated vapor enthalpy at pressure Pe.

15 Xd: Drying rate when coolant at exit of radiator 3 is decompressed up to Pe.

16 Xe: Coolant drying rate at exit of flow control valve 4.

17 X: Drying ratio.   X = Xe / Xd.

18 [0050]

19   The calculation estimating the drying ratio is performed by the following

20 procedure.

21 (Calculation procedure for estimating the drying ratio)

22 (1) hd (coolant enthalpy at the exit of the radiator 3) is calculated using Pd and Td.

23 (2) hf (coolant enthalpy at the entrance of the flow control valve 4) is calculated using

24 Pd and Tf.

25 (3) heL (saturated liquid enthalpy) and heG (saturated vapor enthalpy) are obtained

26 from Pe and the saturation vapor pressure of the coolant.

27 (4) Because the coolant enthalpy does not vary, even if the adiabatic expansion of the

28 coolant is performed and the coolant is decompressed, Xd (drying rate when the

29 coolant at the exit of the radiator 3 is decompressed up to Pe), Xe (coolant drying rate

30 at the exit of the flow control valve 4), and the drying ratio X are calculated as follows.

1   Here, in the drying rate calculation, when the value becomes negative the value is set

2   to zero, meanwhile when the value becomes not smaller than "1" the value is set to

3   "1".

4

5        $Xd = (hd - heL) / (heG - heL)$ (Eq. 5)

6        $Xe = (hf - heL) / (heG - heL)$ (Eq. 6)

7        $X = (hf - heL) / (hd - heL)$ (Eq. 7)

8

9   [0051]

10   The drying-ratio control-range determination unit 16B has drying-ratio data

11   in which the COP becomes the maximum at respective points obtained when the

12   radiation pressure Pd and the evaporation temperature Te are varied with a

13   predetermined interval width in the range of Pd and Te conditions in which the air

14   conditioner may operates (hereinafter referred to as the most suitable operational

15   drying ratio data). For example, assuming that Pd is 9 - 11 MPa and the interval

16   width is 1 MPa, and Te is 0 - 15 degrees and the interval width is 5 degrees, when the

17   COP represented in Fig. 5 becomes the maximum value, the drying ratio data

18   represents to the most suitable operational drying ratio data. The control range of

19   the drying ratio is determined as follows using the most suitable operational drying

20   ratio data.

21   (1) In response to the values of Pd and Te in the current operational state, the drying

22   ratio when the COP becomes the maximum is obtained by interpolating the most

23   suitable operational drying ratio data (hereinafter referred to as the most suitable

24   drying ratio Xmax).

25   (2) A predetermined range such as the difference from the most suitable drying ratio

26   Xmax being within 0.1 is determined to be the control range.

27   The predetermined range width is determined to be a width in which the COP little

28   changes in response to the variation of the drying ratio.

29   [0052]

30   For example, in an operational state in which Pd is 10 MPa, and Te is 10

1   degrees, Xmax is 0.29; then, the control range of the drying ratio falls to 0.19 - 0.39.

2   As found in Fig. 5(b), if the drying ratio is in this control range, the COP varies less

3   than 0.02 from the maximum value. The coolant flow controller 16C checks whether

4   the drying ratio estimated by the drying-ratio estimation unit 16A is within the control

5   range obtained by the drying-ratio control-range determination unit 16B, and if the

6   drying ratio is not within the control range, the coolant flow controller 16C controls

7   either or both of the operational frequency of the second compressor 10 and the flow

8   command of the second flow control valve 12, so as to be in the control range. When

9   the control is performed, suitable PID control is assumed to be performed. When the

10   estimated drying ratio is larger, by increasing the cooling amount in the coolant cooler

11   15, the drying ratio is decreased, meanwhile when the estimated drying ratio is less,

12   by decreasing the cooling amount in the coolant cooler 15, the drying ratio is increased.

13   Here, if the operational frequency of the second compressor 10 is increased, the cooling

14   amount increases, and if the flow command of the second flow control valve 12 is

15   increased, the cooling amount increases.

16   [0053]

17   In the configuration of this Embodiment 5, it is also effective that, by suitably

18   controlling the heat-exchanging amount in the coolant cooling means using the

19   heat-exchanging control means, the COP can surely be improved. It is also effective

20   that, even if usage of the second coolant that is flammable or its global warming

21   potential is inferior to that of the first coolant is decreased, the COP equivalent to that

22   of a case in which only the second coolant is used can be realized. Moreover, the

23   coolant circuit of the second coolant can be configured by a closed loop outside a room;

24   thereby, leakage of the second coolant inside the room can be prevented.

25   Furthermore, a drying-ratio prediction means is provided to estimate the

26   drying ratio, and the heat-exchanging amount is controlled in the coolant cooling

27   means so that the drying ratio falls to a value where the COP is within a range close to

28   the maximum value; therefore, it is effective that the COP can surely be improved.

29   [0054]

30   Although, in this Embodiment 5, the pressure gauge P1 as the first pressure

1 measuring means is provided at the exit of the flow control valve 4, the pressure gauge

2 P1 may be provided at any position between the exit of the flow control valve 4 and the

3 entrance of the evaporator 5. However, in a case in which an apparatus, such as a

4 compressor or another flow control valve, for varying the coolant pressure is provided

5 at a position between the exit of the flow control valve 4 and the entrance of the

6 evaporator 5, the pressure gauge is to be provided between the exit of the flow control

7 valve 4 and the entrance of the apparatus. The pressure gauge P2 as the second

8 pressure measuring means may be provided at any position between the exit of the

9 compressor and the entrance of the flow control valve 4. Here, in a case in which two

10 or more than two compressors are provided, the most high-pressure-side compressor is

11 selected as the target.

12 Although, in the drying-ratio estimation unit 16A, the pressure Pe at the exit

13 of the flow control valve 4 is measured by the pressure gauge P1 and is used, the

14 temperature Te at the exit of the flow control valve 4 may be measured and used.

15 The reason is because the coolant at the exit of the flow control valve 4 is in a

16 gas-liquid two-phase state, and if either the temperature or the pressure is determined,

17 the other one is also determined. Moreover, although the control range is obtained in

18 the drying-ratio control-range determination unit 16B considering Pd and Te, the

19 control range may be obtained considering not Te but Pe.

20 [0055]

21 Although, in the drying-ratio control-range determination unit 16B, the most

22 suitable operational drying ratio data that is drying ratio data when the COP takes

23 the maximum value by combining Pd with Te is used, data in which the difference

24 from the maximum value of the COP is within a predetermined range may be used.

25 Although the most suitable operational drying ratio data is obtained by

26 interpolating to Pd and Te, the value at the nearest point may be used without

27 interpolation.

28 Although the range width is fixed for obtaining the control range from the

29 most suitable drying ratio, the width of the control range may be variable, for example,

30 the difference from the COP is set to be within a predetermined value. Moreover, in

1   the control range, the most suitable drying ratio is not necessary to be included, for

2   example, a predetermined range that is larger than the most suitable drying ratio may

3   be used. Although the most suitable operational drying ratio data is prepared in

4   which both Pd and Te are varied, either Pd or Te may be fixed. A different control

5   range in response to a set of Pd and Te is not searched, but, by specifying only one of

6   Pd and Te, if unspecified one is within an estimated varying range, the drying ratio

7   control range may be searched so that, regarding the COP, the difference from the

8   maximum value is lower than a predetermined value. Furthermore, if the value is

9   within an estimated varying range in response to both Pd and Te, the drying ratio

10   control range is previously searched so that, regarding the COP, the difference from

11   the maximum value is lower than a predetermined value; then, the value may be

12   outputted.

13   If the drying-ratio control-range determination unit 16B determines the

14   drying ratio control range in which the difference from the maximum value of the COP

15   falls to within the predetermined range, any unit may be used.

16   [0056]

17   Although in the coolant flow controller 16C, the PID control has been

18   performed so that as the drying ratio is kept within the control range, a controller may

19   also be used in which the cooling amount is controlled by the coolant cooling means so

20   that the drying ratio falls to a specified value. According to control errors, if the

21   control is performed to keep at a specified value, the control is resultantly performed

22   within a predetermined range close to the specified value. The specified value may be

23   determined, considering the value of the control error, so that the drying ratio does not

24   exceed the control range, even if the control error is included. The drying ratio need

25   not necessary be specified in which the COP becomes the maximum value. When the

26   drying ratio is controlled within the control range, the control may also be performed

27   by other than the PID control.

28   [0057]

29   Here, in this Embodiment 5, although a case in which the configuration is

30   applied to that in Embodiment 1 has been explained, in a case in which the

1 configuration is applied to any one of the configurations, or any one of configurations

2 simultaneously having characteristics of those configurations, included in

3 Embodiment 2 through Embodiment 4, an effect similar to that can also be obtained.

4 Moreover, in a case in which the coolant cooling means does not use a

5 vapor-compression refrigeration cycle, even if the cooling amount is controlled so that

6 the drying ratio is estimated and falls to within the predetermined range, an effect

7 similar to the above can also be obtained. Not drying ratio, but flow-control-valve

8 entrance temperature as coolant temperature at the entrance of the flow control valve

9 4 may also be used as an indicator and controlled. These facts are also applied to the

10 other embodiments.

11

12 [0058]

13 Embodiment 6.

14   Fig. 12 is a coolant-circuit diagram illustrating a configuration of an air

15 conditioner according to Embodiment 6. In Embodiment 6, Embodiment 5 is

16 modified so that the pressure gauge for estimating the drying ratio is not used. Only

17 different elements comparing with those in Fig. 10 according to Embodiment 5 are

18 explained. Instead of the pressure gauges P1 and P2, the thermometer T1 as the first

19 temperature measuring means provided at the exit of the flow control valve 4, a

20 thermometer T4 as a fourth temperature measuring means provided at the exit of the

21 radiator 3, and a thermometer T5 as a fifth temperature measuring means provided at

22 the entrance of the radiator 3 are provided. Measurement values by the

23 thermometers T1, T2, T3, T4, and T5 as predetermined sensors are inputted into the

24 drying-ratio estimation unit 16A. The other configurations are the same as those in

25 Embodiment 5.

26

27 [0059]

28   The coolant flow is the same as that in Embodiment 5. The operation of the

29 heat exchanging controller 16 is also similar to that in Embodiment 5. A procedure

30 for estimating the drying ratio in the drying-ratio estimation unit 16A is differed from

1   that in Embodiment 5.   If the radiation pressure Pd and the evaporation pressure Pe

2   can be estimated, the drying ratio can be estimated similarly to that in Embodiment 5;

3   therefore, a method of estimating the radiation pressure Pd and the evaporation

4   pressure Pe is explained.   Therefore, the following parameters for representing the

5   coolant state are additionally defined.   Here, Te is directly measured by the

6   thermometer T1.

7   (Definition of parameters for explaining coolant state)

8   Tc: Coolant temperature at exit of radiator 3.   Measured by thermometer T4.

9   Tb: Coolant temperature at entrance of radiator 3.   Measured by thermometer T5.

10   Tx: Overheat rate of coolant inhaled into compressor 3.

11   [0060]

12   A method of estimating the radiation pressure Pd and the evaporation

13   pressure Pe becomes as follows.

14   (Estimation method for radiation pressure Pd and evaporation pressure Pe)

15   (1) Pe is obtained from Te and the saturation vapor pressure of the coolant.

16   (2) Overheat rate Tx is obtained from Tc and Td.

17   (3) Pd is calculated using Pe and Tx, the efficiency of the compressor, and Tb.

18   [0061]

19   In the configuration of this Embodiment 6, it is also effective that, by suitably

20   controlling the heat-exchanging amount in the coolant cooling means, using the

21   heat-exchanging control means, the COP can surely be improved.   It is also effective

22   that, even if usage of the second coolant that is flammable or its global warming

23   potential is inferior to that of the first coolant is decreased, the COP equivalent to that

24   of a case in which only the second coolant is used can be realized.   Moreover, the

25   coolant circuit of the second coolant can be configured by a closed loop outside a room;

26   thereby, leakage of the second coolant inside the room can be prevented.   The control

27   is performed with providing the drying-ratio estimation means and estimating the

28   drying ratio; thereby, it is effective that the COP can surely be improved.

29   Furthermore, it is effective that only a low-cost temperature sensor

30   (thermometer) is used for the drying-ratio estimation means.   However, because the

1 pressure is not actually measured, the accuracy may deteriorate from that in

2 Embodiment 5. Here, although the pressure between the flow control valve 4 and the

3 compressor 3 has been assumed to be constant, because a pressure loss occurs in the

4 heat exchanger, etc., points where pressure is measured are specifically needed to be

5 increased. Considering the balance between the accuracy and the cost, the kind and

6 the number of the sensors are determined. These are also applied to the other

7 embodiments.

8 [0062]

9   Here, in this Embodiment 6, although a case in which the configuration is

10 applied to that in Embodiment 1 has been explained, in a case in which the

11 configuration is applied to any one of the configurations, or any one of configurations

12 simultaneously having characteristics of those configurations, included in

13 Embodiment 2 through Embodiment 4, an effect similar to that can also be obtained.

14

15 [0063]

16 Embodiment 7.

17   Fig. 13 is a coolant-circuit diagram illustrating a configuration of an air

18 conditioner according to Embodiment 7. In Embodiment 7, Embodiment 1 is

19 modified so that the control is performed not by the drying ratio but by the

20 flow-control-valve entrance temperature having been measured. Only different

21 elements comparing with those in Fig. 1 according to Embodiment 1 are explained.

22   In Fig. 13, the thermometer T2 is additionally provided as the second

23 temperature measuring means provided at the entrance of the flow control valve 4.

24 Moreover, the heat exchanging controller 16 is configured of a

25 flow-control-valve-entrance-temperature control-range determination unit 16D as a

26 flow-control-valve-entrance-temperature control-range determination means for

27 obtaining a temperature range, in which the difference from the maximum value of

28 the COP among values, when temperature at the entrance of the flow control valve is

29 varied, falls to within a predetermined range, at the entrance of the flow control valve,

30 and the coolant flow controller 16C as the control means for controlling the coolant

1 flow so that the temperature at the entrance of the flow control valve falls to within

2 the control range obtained by the flow-control-valve-entrance-temperature

3 control-range determination unit 16D. The coolant flow controller 16C can control

4 the command value in response to the operational frequency of the second compressor

5 10 and to the second flow control valve 12.

6 The other configurations are the same as those in Embodiment 1.

7 [0064]

8 Next, an operation is explained. Coolant flow is the same as that in

9 Embodiment 1. Hereinafter, an operation of the heat exchanger 16 is explained.

10 Here, temperature at the entrance of the flow control valve is measured using the

11 thermometer T2, and represented by the parameter Tf.

12 The flow-control-valve-entrance-temperature control-range determination

13 unit 16D outputs a previously obtained control range of the temperature at the

14 entrance of the flow control valve. Here, the previously obtained control range of the

15 temperature at the entrance of the flow control valve means a range of the

16 temperature at the entrance of the flow control valve (hereinafter referred to as the

17 most suitable range), when the difference from the maximum value of the COP at the

18 predetermined values of Pd and Te falls to within a predetermined range, assuming

19 that the radiation pressure Pd and the evaporation temperature Te operate at a

20 predetermined design value. For example, when Pd is 10 MPa, and Te is 10 degrees,

21 providing that the COP ratio in Fig. 4(b) is within a range of not larger than 0.05 from

22 the maximum value, the most suitable range falls to a range in which Tf is between 15

23 and 27 degrees.

24 [0065]

25 In the coolant flow controller 16C, the temperature at the entrance of the flow

26 control valve measured by the thermometer T2 is checked whether the temperature is

27 within the most suitable range obtained by the

28 flow-control-valve-entrance-temperature control-range determination unit 16D, that is,

29 whether the temperature is within the control range, and, if the temperature is not

30 within the control range, either or both the operational frequency of the second

1 compressor 10 and the command value of the flowing amount into the second flow

2 control valve 12 are controlled so as to fall to within the control range. In the

3 controlling, suitable PID control is used in this case. When the estimated

4 measured-temperature at the entrance of the flow control valve is higher, the

5 temperature at the entrance of the flow control valve is decreased by the cooling

6 amount in the coolant cooler 15 being increased; meanwhile, when the estimated

7 temperature at the entrance of the flow control valve is lower, the temperature at the

8 entrance of the flow control valve is increased by the cooling amount in the coolant

9 cooler 15 being decreased.

10 [0066]

11   In the configuration of this Embodiment 7, it is also effective that, by suitably

12 controlling the heat-exchanging amount in the coolant cooling means, using the

13 heat-exchanging control means, the COP can surely be improved. It is also effective

14 that, even if usage of the second coolant that is flammable or its global warming

15 potential is inferior to that of the first coolant is decreased, the COP equivalent to that

16 of a case in which only the second coolant is used can be realized. Moreover, the

17 coolant circuit of the second coolant can be configured by a closed loop outside a room;

18 thereby, leakage of the second coolant inside the room can be prevented.

19   Furthermore, the temperature at the entrance of the flow control valve is

20 measured, and the heat-exchanging amount is controlled by the coolant cooling means

21 so that the temperature measured falls to the temperature, where the COP falls to

22 within the range close to the maximum value, at the entrance of the flow control valve;

23 thereby, it is effective that the COP can surely be improved.

24 [0067]

25   The explanation related to the drying-ratio control-range determination unit

26 16B is also applied to that related to the flow-control-valve-entrance-temperature

27 control-range determination unit 16D by changing the drying ratio to the temperature

28 at the entrance of the flow control valve. The explanation related to the coolant flow

29 controller 16C is also similar. This is also applied to the other embodiments in which

30 the control is performed using the temperature at the entrance of the flow control

1 valve.

2 [0068]

3   Here, in this Embodiment 7, although a case in which the configuration is

4 applied to that in Embodiment 1 has been explained, in a case in which the

5 configuration is applied to any one of the configurations, or any one of configurations

6 simultaneously having characteristics of those configurations, included in

7 Embodiment 2 through Embodiment 4, an effect similar to that can also be obtained.

8

9 [0069]

10 Embodiment 8.

11   Fig. 14 is a coolant-circuit diagram illustrating a configuration of an air

12 conditioner according to Embodiment 8. In Embodiment 8, Embodiment 7 is

13 modified in such a way that the heat-exchanging amount is controlled in the coolant

14 cooler 15 so that, by measuring the coolant temperature at the entrance of the coolant

15 cooler 15, the coolant temperature at the exit of the coolant cooler 15, that is, at the

16 entrance of the flow control valve 4 (temperature at the entrance of the flow control

17 valve), is controlled, in which the COP becomes the maximum value. Only different

18 elements comparing with those in Fig. 13 according to Embodiment 7 are explained.

19   In Fig. 14, instead of the thermometer T2, the thermometer T3 is provided as

20 the third temperature measuring means provided at the exit of the radiator 3. The

21 pressure gauge P2 as the second pressure measuring means provided between the exit

22 of the second heat exchanger 13 and the entrance of the flow control valve 4, and the

23 thermometer T1 as the first temperature measuring means provided at the exit of the

24 flow   control   valve   4   are   additionally   provided.   The

25 flow-control-valve-entrance-temperature control-range determination unit 16D is also

26 to be a flow-control-valve-entrance-temperature estimation means.

27   The other configurations are the same as those in Embodiment 7.

28 [0070]

29   Next, an operation is explained. Coolant flow is the same as that in

30 Embodiment 1. Hereinafter, an operation of the heat exchanger 16 is explained.

1   The flow-control-valve-entrance-temperature control-range determination unit 16D

2   has temperature data at the entrance of the flow control valve when the COP becomes

3   the maximum value among the values of points that generate when the radiation

4   pressure Pd and the evaporation temperature Te are varied with a predetermined

5   interval width in the range of Pd and Te conditions in which the air conditioner may

6   operates (hereinafter referred to as the most suitable operational

7   flow-control-valve-entrance-temperature data). For example, assuming that Pd is 9 -

8   11 MPa, whose interval width is 1 MPa, and Te is 0 - 15 degrees, whose interval width

9   is 5 degrees, when the COP represented in Fig. 5 becomes the maximum value, the

10   temperature data at the entrance of the flow-control-valve represents the most

11   suitable operational flow-control-valve-entrance-temperature data.

12   [0071]

13   In this Embodiment 8, the reference value of temperature at the entrance of

14   the flow control valve is determined as follows from the most suitable operational

15   flow-control-valve-entrance-temperature data. The most suitable operational

16   flow-control-valve-entrance-temperature data is obtained that positions at the nearest

17   point in response to the values of Pd and Te in the present operational state. If Pd is

18   10.2 MPa and Te is 8.5 degrees, the most suitable operational

19   flow-control-valve-entrance-temperature data when Pd is 10 MPa, and Te is 10

20   degrees is obtained. Hereinafter, the obtained flow-control-valve entrance

21   temperature is referred to as reference flow-control-valve entrance temperature Tfm.

22   Here, when a plurality of the nearest ones is included, one of them is selected based on

23   any rule, for example, the one having the highest flow-control-valve entrance

24   temperature is selected.

25   [0072]

26   The coolant flow controller 16C determines the flow volume of the second

27   coolant as follows, and controls the operational frequency of the second compressor 10

28   so as to keep the flow volume. Due to a control error, etc., the operational state in

29   which the COP becomes the maximum is not necessarily realized; however, it can be

30   ensured that the operation can be performed in a state in which the COP is close to the

1 maximum.

2 (1) A heat-exchanging amount in the coolant cooler 15 is determined from Td and Tfm.

3 (2) The flow volume of the second coolant is determined from the heat-exchanging

4 amount considering various conditions such as the efficiency of the second heat

5 exchanger 13, and temperature of the second coolant inhaled into the second heat

6 exchanger 13.

7 (3) Considering the characteristics of the second compressor 10, and the state of the

8 second flow control valve 12, etc., an operational frequency of the second compressor

9 10 is determined so as to keep the flow volume calculated in (2), and the control is

10 performed so that the second compressor 10 is set to the operational frequency.

11 [0073]

12 In the configuration of this Embodiment 8, it is also effective that, by suitably

13 controlling the heat-exchanging amount in the coolant cooling means, using the

14 heat-exchanging control means, the COP can surely be improved. It is also effective

15 that, even if usage of the second coolant that is flammable or its global warming

16 potential is inferior to that of the first coolant is decreased, the COP equivalent to that

17 of a case in which only the second coolant is used can be realized. Moreover, the

18 coolant circuit of the second coolant can be configured by a closed loop outside a room;

19 thereby, leakage of the second coolant inside the room can be prevented.

20 Furthermore, the temperature of the coolant inhaled into the coolant cooling

21 means Td, the radiation pressure Pd, and the evaporation temperature Te are

22 measured, the reference flow-control-valve entrance temperature is obtained in which

23 the COP becomes the maximum value at the measured condition, and the

24 heat-exchanging amount is controlled by the coolant cooling means so that the

25 temperature falls to the reference flow-control-valve entrance temperature, that is, the

26 flow volume of the second coolant is controlled; thereby, it is effective that the COP can

27 surely be set close to the maximum value.

28 [0074]

29 A flow-control-valve-entrance-temperature estimating means is provided in

30 addition to the flow-control-valve-entrance-temperature control-range determination

1   unit 16D; thereby, the flow-control-valve-entrance-temperature control-range

2   determination unit 16D may be configured in such a way that the PID control, etc. is

3   performed   in   response   to   a   result   estimated   by   the

4   flow-control-valve-entrance-temperature estimating means. Another control system

5   other than the PID control may be also applied to the above.

6   Here, in this Embodiment 8, although a case in which the configuration is

7   applied to that in Embodiment 1 has been explained, in a case in which the

8   configuration is applied to any one of the configurations, or any one of configurations

9   simultaneously having characteristics of those configurations, included in

10   Embodiment 2 through Embodiment 4, an effect similar to that can also be obtained.

11

12   [0075]

13   Embodiment 9.

14   In Fig. 15, a coolant-circuit diagram is illustrated for explaining a

15   configuration of a cooling only air conditioner according to Embodiment 9 of the

16   present invention. In Embodiment 9, Embodiment 1 is modified by installing double

17   compressors, so that a radiator for radiating coolant heat between the compressors is

18   additionally provided. Only different elements from those in Embodiment 1 are

19   explained. A third radiator 50 for radiating the heat from the coolant as compressed

20   by the compressor 2, and a third compressor 51 for further compressing the coolant as

21   outputted from the third radiator are additionally provided, so that the coolant

22   outputted from the third compressor 51 is inputted into the radiator 3. The coolant is

23   compressed, by the double compressors, to the same pressure as that in Embodiment

24   1.

25   The other configurations are the same as those in Embodiment 1.

26   [0076]

27   Next, an operation is explained. A pressure-enthalpy chart is illustrated in

28   Fig. 16 for explaining the variation of coolant states in an air conditioner in

29   Embodiment 9 according to the present invention. The solid lines represent the case

30   in this Embodiment 9, meanwhile the broken lines represent the case in which the

- 39 -

1 third radiator is not provided.

2 The coolant in the inlet side of the compressor 2 is in a low-temperature and
3 low-pressure vapor state represented by the point "A" in Fig. 16. The coolant
4 outputted from the compressor 2 is in a medium-pressure and medium-temperature
5 vapor state represented by the point "J" positioned on the line A - B. The coolant,
6 after heat is exchanged with air, etc., in the third radiator 50 becomes a state,
7 represented by the point "K", being the same pressure as and a lower temperature
8 than those represented by the point "J". The coolant is further compressed by the
9 third compressor 51, so that the coolant changes into a high-pressure super-critical
10 fluid state represented by the point "M". The coolant state at the point "M" is the
11 same pressure as and a lower temperature than those at the point "B".

12 The locus of the coolant-state variation, after the coolant is inputted into the
13 radiator 3, passes through the coolant cooler 15 and the flow control valve 4, and, until
14 the coolant is inputted into the compressor 2, becomes the locus "M - C - D - E - A" that
15 is the same as the locus in Embodiment 1.

16 [0077]

17 In the configuration of this Embodiment 9, it is also effective that, by suitably
18 controlling the heat-exchanging amount in the coolant cooling means, using the
19 heat-exchanging control means, the COP can surely be improved. It is also effective
20 that, even if usage of the second coolant that is flammable or its global warming
21 potential is inferior to that of the first coolant is decreased, the COP equivalent to that
22 of a case in which only the second coolant is used can be realized. Moreover, the
23 coolant circuit of the second coolant can be configured by a closed loop outside a room;
24 thereby, leakage of the second coolant inside the room can be prevented.

25 [0078]

26 Furthermore, by providing the third radiator 50, it is effective that the COP
27 can be more improved than that in a case in which the third radiator 50 is not
28 provided. The reason is explained as follows. Here, the heat-exchanging amount in
29 the evaporator 5 is the same whether the third radiator 50 is provided or not provided.
30 Because the mechanical input when the third radiator 50 is provided becomes smaller,

the COP is more improved. It is assumed that the enthalpies at the points "A", "B", "J", "K", and "M" are given by Ha, Hb, Hj, Hk, and Hm, respectively. Moreover, it is assumed that the mechanical input when the third radiator 50 is not provided is given by W1, meanwhile the mechanical input when the third radiator 50 is provided is given by W2. The difference between W1 and W2 is represented as follows.

$$W1 = Hb - Ha \qquad\qquad (Eq.\ 8)$$

$$W2 = Hj - Ha + Hm - Hk \qquad\qquad (Eq.\ 9)$$

$$W1 - W2 = Hb - Ha - (Hj - Ha + Hm - Hk)$$
$$= (Hb - Hj) - (Hm - Hk) \qquad\qquad (Eq.\ 10)$$

[0079]

As explained above, even though the pressure values before and after compression are equivalent, the larger the enthalpy value, the more the mechanical input needed for compressing increases. In this case, because the enthalpy at the point "J" is larger than that at the point "K", the enthalpy difference along the line segment KM becomes greater than that along the line segment JB; thereby, Eq. 10 becomes necessarily positive.

Here, in this Embodiment 9, although a case in which the configuration is applied to that in Embodiment 1 has been explained, in a case in which the configuration is applied to any one of the configurations, or any one of configurations simultaneously having characteristics of those configurations, included in Embodiment 4 through Embodiment 8, an effect similar to that can also be obtained.

[0080]

Embodiment 10.

In Fig. 17, a coolant-circuit diagram is illustrated for explaining a configuration of an air conditioner having cooling and warming functions according to Embodiment 10 of the present invention. In Embodiment 10, Embodiment 3 is modified by installing double compressors, so that a radiator for radiating coolant heat

1 is additionally provided between the compressors. Only different elements from

2 those in Fig. 7 according to Embodiment 3 are explained.

3 The third radiator 50 for radiating heat from the coolant compressed by the

4 compressor 2, the third compressor 51 for further compressing the coolant outputted

5 from the third radiator 50, and a flow-route switching valve 52 as a flow-route

6 changing means for directly inputting, during the warming operation, the coolant into

7 the third compressor without circulating it into the third radiator 50 are additionally

8 provided, so that the coolant outputted from the third compressor 51 is inputted into

9 the four-way valve 20. Using the double compressors, the coolant is compressed up to

10 the same pressure as that in Embodiment 3.

11 The flow-route switching valve 52 is provided between the compressor 2 and

12 the third radiator 50. The flow-route switching valve 52 can circulate the coolant to

13 either a coolant pipe 6A for inputting it into the third radiator 50 or a coolant pipe 6B

14 connected to the coolant pipe 6 connecting the third radiator 50 with the third

15 compressor 51. The other configurations are the same as those in Embodiment 3.

16 [0081]

17 Next, an operation is explained. During the cooling operation, the flow-route

18 switching valve 52 circulates the coolant to the coolant pipe 6A, that is, circulates it to

19 the third radiator 50, so as to operate similarly to that in Embodiment 9.

20 During the warming operation, because the flow-route switching valve 52

21 flows the coolant through the coolant pipe 6B, and does not flow it into the third

22 radiator 50, the air conditioner operates similarly to that in Embodiment 3. In

23 Embodiment 3, the single compressor 2 compresses the coolant; accordingly, the

24 difference is only that the compressor 2 and the third compressor 51 compress the

25 coolant.

26 [0082]

27 Even in the configuration of this Embodiment 10, it is effective that, by

28 suitably controlling the heat-exchanging amount in the coolant cooling means, using

29 the heat-exchanging control means, the COP can surely be improved. It is also

30 effective that, even if usage of the second coolant that is flammable or its global

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warming potential is inferior to that of the first coolant is decreased, the COP equivalent to that of a case in which only the second coolant is used can be realized. The coolant circuit of the second coolant can be configured by a closed loop outside a room; thereby, leakage of the second coolant inside the room can be prevented.

Moreover, during the warming operation, it is effective that the COP can also be improved.

Furthermore, it is effective that, by providing the third radiator 50, the COP can be more improved than that in a case in which the third radiator 50 is not provided.

[0083]

The flow-route switching valve 52 may be provided between the third radiator 50 and the third compressor 51. Moreover, the flow-route switching valves 52 may be provided on both sides of the third radiator 50. Any part may be applied as the flow-route switching valve 52, if it can circulate the coolant into the predetermined unit only during the cooling operation. These are also applied to the other embodiments having the flow-route switching valve 52.

[0084]

Here, in this Embodiment 10, although a case in which the configuration is applied to that in Embodiment 3 has been explained, in a case in which the configuration is applied to either Embodiment 2 or Embodiment 3 in which the characteristics of the configurations in Embodiment 2, and in Embodiment 4 through Embodiment 8 are additionally provided, an effect similar to that can also be obtained.

[0085]

Embodiment 11.

In Fig. 18, a coolant-circuit diagram is illustrated for explaining a configuration of a cooling only air conditioner according to Embodiment 11 of the present invention. In Embodiment 11, Embodiment 9 is modified so that a heat exchanger for cooling the coolant by the second coolant is additionally provided between the third radiator 50 and the third compressor 51. Only different elements

1   from those in Fig. 16 according to Embodiment 9 are explained.

2   In Fig. 18, a third heat exchanger 60 is additionally provided for exchanging

3   heat between the second coolant from the second heat exchanger 13 and the coolant

4   from the third radiator 50. The coolant outputted from the third heat exchanger 60 is

5   inputted into the third compressor 51, meanwhile the second coolant outputted from

6   the third heat exchanger 60 is inputted into the second compressor.

7   The other configurations are the same as those in Embodiment 9.

8   [0086]

9   Next, an operation is explained. A pressure-enthalpy chart is illustrated in

10 Fig. 19 for explaining the variation of coolant states of the air conditioner in

11 Embodiment 11 according to the present invention. The solid lines represent the case

12 in this Embodiment 11, meanwhile the broken lines represent the case in which the

13 third heat exchanger 60 is not provided.

14 The locus of the coolant states, after the coolant is inhaled into the compressor

15 and until outputted from the third heat exchanger 60, becomes the same locus "A - J -

16 K" as that in Embodiment 9. The coolant is further cooled by the second coolant in

17 the third heat exchanger 60; then, the coolant becomes the same pressure represented

18 by the point "N" as that represented by the point "K", and further lower temperature

19 state. The coolant is further compressed by the third compressor 51, and then,

20 becomes a high-pressure supercritical fluid state represented by the point "O". In the

21 coolant state at the point "O", the pressure is the same as that at the point "M",

22 meanwhile its temperature is lower. The locus of the coolant-state variation, after

23 the coolant is inputted into the radiator 3 and until inputted into the compressor 2,

24 becomes the same locus "M- C - D - E - A" as that in Embodiment 1.

25 [0087]

26 In the configuration of this Embodiment 11, it is also effective that, by suitably

27 controlling the heat-exchanging amount in the coolant cooling means, using the

28 heat-exchanging control means, the COP can surely be improved. It is also effective

29 that, even if usage of the second coolant that is flammable or its global warming

30 potential is inferior to that of the first coolant is decreased, the COP equivalent to that

1 of a case in which only the second coolant is used can be realized. The coolant circuit

2 of the second coolant can be configured by a closed loop outside a room, and leakage of

3 the second coolant inside the room can be prevented. Moreover, by providing the

4 third radiator 50, it is also effective that the COP can be more improved than that in a

5 case in which the third radiator 50 is not provided.

6 Furthermore, by providing the third heat exchanger 60, it is also effective that

7 the COP can be more improved than that in a case in which the third heat exchanger

8 60 is not provided. The reason that the COP is improved by providing the third heat

9 exchanger 60 is because, similar to the case when the third radiator 50 is provided,

10 mechanical input in the third compressor 51 is reduced when the enthalpy of the

11 coolant inputted into the third compressor 51 is decreased.

12 [0088]

13 Regarding the second coolant flowing in the third heat exchanger 60, the

14 temperature is increased after the heat exchanged is performed by the coolant in the

15 second heat exchanger 13; therefore, by the heat exchanged in the third heat

16 exchanger 60, the mechanical input of the second-coolant cooling cycle is little

17 increased. However, because the heat exchange amount in the second heat

18 exchanger 13 is controlled so as to enable the COP to improve, the heat exchange

19 amount in the third heat exchanger 60 cannot independently be determined.

20 Although the second coolant is flowed using the second heat exchanger 13 and

21 the third heat exchanger 60 connected together in series, the second coolant may be

22 flowed in parallel. By adding either or both of a compressor and a radiator, the

23 coolant circuit of the second coolant flowing in the third heat exchanger 60 and the

24 coolant circuit of the second coolant flowing in the second heat exchanger 13 may be

25 separated. In such case, as the coolant flowing in the third heat exchanger 60, a

26 coolant other than the second coolant may be used.

27 [0089]

28 The third radiator 50 is not necessary to be provided. In a case in which the

29 temperature of the coolant outputted from the compressor 2 is higher than that of the

30 outdoor air, the COP when the third radiator 50 is provided can be more improved.

1   The reason is because the heat exchange amount in the third radiator 50 decreases

2   because only a portion that is not cooled by the outdoor air may be cooled by the third

3   radiator 50, and as a result, the mechanical input in the second compressor 10 is

4   reduced.

5   [0090]

6   Here, in this Embodiment 11, although a case in which the configuration is

7   applied to that in Embodiment 9 has been explained, in a case in which the

8   configuration is applied to any one of the configurations or any one of configurations

9   simultaneously having the characteristics of the configurations, included in

10   Embodiment 1, Embodiment 2, and Embodiment 4 through Embodiment 8, an effect

11   similar to that can also be obtained.

12

13   [0091]

14   Embodiment 12.

15   In Fig. 20, a coolant-circuit diagram is illustrated for explaining a

16   configuration of a cooling only air conditioner according to Embodiment 12 of the

17   present invention.   In Embodiment 12, Embodiment 11 is modified so that the coolant

18   is flowed in parallel in the third heat exchanger 60 and the second heat exchanger 13.

19   Only different elements from those in Fig. 18 according to Embodiment 11 are

20   explained.   Here, Embodiment 12 is also configured based on Embodiment 9, and a

21   different modification from Embodiment 11 is performed.

22   In Fig. 20, a second bypass pipe 70 for introducing the second coolant into the

23   third heat exchanger 60, and a forth flow control valve 71 for regulating the flow

24   volume of the second coolant flowing into the third heat exchanger 60 are additionally

25   provided.   Both of the forth flow control valve 71 and the second flow control valve 12

26   are arranged so as to flow in parallel the coolant outputted from the condenser 11.

27   The second coolant flows through the forth flow control valve 71, the second bypass

28   pipe 70, the third heat exchanger 60, and the second compressor 10, in that sequence.

29   The other configurations are the same as those in Embodiment 11.

30   [0092]

1   Next, an operation is explained. The variation of coolant states of the air

2   conditioner in Embodiment 12 according to the present invention becomes the same as

3   that in Fig. 19 according to Embodiment 11.

4   [0093]

5   Because the variation of the coolant states is the same as that in Embodiment

6   11, Embodiment 12 also has the effect as Embodiment 11. Moreover, because the

7   forth flow control valve 71 is provided therein, the flow volume of the second coolant

8   flowing in the third heat exchanger 60 can be independently controlled from the flow

9   volume of the second coolant flowing in the second heat exchanger 13; therefore, it is

10   effective that an operational condition when the COP becomes the maximum is easy to

11   be realized.

12   [0094]

13   Here, in this Embodiment 12, although a case in which the configuration is

14   applied to that in Embodiment 9 has been explained, in a case in which the

15   configuration is applied to any one of the configurations or any one of configurations

16   simultaneously having the characteristics of the configurations, included in

17   Embodiment 1 through Embodiment 8, and Embodiment 10, an effect similar to that

18   can also be obtained.

19

20   [0095]

21   Embodiment 13.

22   In Fig. 21, a coolant-circuit diagram is illustrated for explaining a

23   configuration of an air conditioner having cooling and warming functions according to

24   Embodiment 13 of the present invention. In Embodiment 13, Embodiment 2 is

25   modified by installing double compressors, so that the third heat exchanger 60 is

26   additionally provided between the compressors for exchanging heat between the

27   coolant and the second coolant. Only different elements from those in Fig. 6

28   according to Embodiment 2 are explained.

29   In Fig. 21, a third heat exchanger 60 and a third compressor 51 are

30   additionally installed between the compressor 2 and the four-way valve 20. The

1 coolant outputted from the compressor 2 flows through the third heat exchanger 60

2 and the third compressor 51, and is inputted into the four-way valve 20, in that

3 sequence.

4 The other configurations are the same as those in Embodiment 2.

5 [0096]

6 Next, an operation is explained. During a cooling operation, the variation of

7 coolant states in the air conditioner according to Embodiment 12 of the present

8 invention approximately becomes the same as that in Fig. 16 according to

9 Embodiment 9. However, the locus "J - K" as the variation of the coolant stats is

10 given not by the third radiator 50 but by the third heat exchanger 60.

11 During a warming operation, because the coolant cooler 15 is not operated

12 similarly to that in Embodiment 2, the locus of the variation of the coolant states

13 during the warming operation becomes the same locus as the locus "A - B - C - F - A" in

14 Fig. 2 according to Embodiment 2.

15 [0097]

16 In the configuration of this Embodiment 13, during the cooling operation, it is

17 also effective that, by suitably controlling the heat-exchanging amount in the coolant

18 cooling means, using the heat-exchanging control means, the COP can surely be

19 improved. It is also effective that, even if usage of the second coolant that is

20 flammable or its global warming potential is inferior to that of the first coolant is

21 decreased, the COP equivalent to that of a case in which only the second coolant is

22 used can be realized. Moreover, the coolant circuit of the second coolant can be

23 configured by a closed loop outside a room; thereby, leakage of the second coolant

24 inside the room can be prevented.

25 Furthermore, it is effective that, by providing the third heat exchanger 60, the

26 COP can be more improved than that in a case in which the third heat exchanger 60 is

27 not provided.

28

29 [0098]

30 Embodiment 14.

1   In Fig. 22, a coolant-circuit diagram is illustrated for explaining a

2   configuration of an air conditioner having cooling and warming functions according to

3   Embodiment 14 of the present invention. In Embodiment 14, Embodiment 13 is

4   modified, so that the coolant is flowed in parallel in the third heat exchanger 60 and

5   the second heat exchanger 13. Only different elements from those in Fig. 21

6   according to Embodiment 13 are explained.

7   In Fig. 22, the second bypass pipe 70 for introducing the second coolant into

8   the third heat exchanger 60, and the forth flow control valve 71 for regulating the flow

9   volume of the second coolant flowing in the third heat exchanger 60 are additionally

10   provided. Both of the forth flow control valve 71 and the second flow control valve 12

11   are installed so as to flow in parallel the coolant outputted from the condenser 11.

12   The second coolant flows through the forth flow control valve 71, the second bypass

13   pipe 70, the third heat exchanger 60, and the second compressor 10, in that sequence.

14   The other configurations are the same as those in Embodiment 13.

15   [0099]

16   Next, an operation is explained. During a cooling operation, the variation of

17   coolant states in the air conditioner according to Embodiment 14 of the present

18   invention, similarly to that in Embodiment 13, approximately becomes the same as

19   that in Fig. 16 according to Embodiment 9. Although a point in which the variation

20   of the coolant states in the locus "J - K" is given not by the third radiator 50 but by the

21   third heat exchanger 60 is differed from that in Fig. 16, the point is the same as that

22   in Embodiment 13.

23   [0100]

24   Because the variation of the coolant states in Embodiment 14 is the same as

25   that in Embodiment 13, the same effect as that in Embodiment 13 is also obtained in

26   this Embodiment 14.

27   Moreover, because the forth flow control valve 71 is provided therein, the flow

28   volume of the second coolant flowing in the third heat exchanger 60 can be

29   independently controlled from the flow volume of the second coolant flowing in the

30   second heat exchanger 13; therefore, it is effective that an operational condition when

1   the COP becomes the maximum is easy to be realized.

2

3   [0101]

4   Embodiment 15.

5   In Fig. 23, a coolant-circuit diagram is illustrated for explaining a

6   configuration of an air conditioner having cooling and warming functions according to

7   Embodiment 15 of the present invention. In Embodiment 15, Embodiment 3 is

8   modified by installing double compressors, so that the third heat exchanger 60 is

9   additionally provided between the compressors for exchanging heat between the

10   coolant and the second coolant during a cooling operation. Only different elements

11   from those in Fig. 7 according to Embodiment 3 are explained.

12   In Fig. 23, the third heat exchanger 60, the third compressor 51, and the

13   floe-route switching valve 52 as a flow-route switching means for directly inputting the

14   coolant, during a warming operation, into the third compressor 51 without flowing it

15   into the third heat exchanger 60 are additionally provided between the compressor 2

16   and the four-way valve 20. The coolant outputted from the compressor 2 flows

17   through the third heat exchanger 60 and the third compressor 51; then, the coolant is

18   inputted into the four-way valve 20, in that sequence. Compression is performed,

19   using the double compressors, up to the same pressure as that in Embodiment 3.

20   The flow-route switching valve 52 is provided between the compressor 2 and

21   the third heat exchanger 60. By the flow-route switching valve 52, the coolant can be

22   flowed in either the coolant pipe 6A introducing it to the third heat exchanger 60 or

23   the coolant pipe 6B connected to the coolant pipe 6 that connects the third heat

24   exchanger 60 with the third compressor 51.

25   The other configurations are the same as those in Embodiment 3.

26   [0102]

27   Next, an operation is explained. During a cooling operation, the flow-route

28   switching valve 52 flows the coolant through the coolant pipe 6A, that is, flows it into

29   the third heat exchanger 60, which operates similar to that in Embodiment 13.

30   During a warming operation, because the flow-route switching valve 52 flows

the coolant through the coolant pipe 6B, but does not flow it into the third heat exchanger 60, the air conditioner operates similar to that in Embodiment 3. The reason in which the coolant is not flowed into the third heat exchanger 60 during the warming operation is because the COP is not to be decreased. If the coolant is flowed in the third heat exchanger 60 during the warming operation, the enthalpy of the coolant inputted into the third compressor 51 increases; thereby, the mechanical input in the third compressor 51 is increased. Although a heat amount radiated by the indoor heat exchanger 22 is also increased, the increasing heat amount is approximately equivalent to the increase of the mechanical input in the third compressor 51; therefore, regarding only the increase, the COP is "1". Because the COP when the coolant does not flow in the third heat exchanger 60 is larger than "1", when the COP only due to the increase is "1", the COP decreases.

[0103]

Here, in a case in which the high temperature is needed during the warming operation, and the overheat rate of the coolant inputted into the compressor 2 is needed to be at a predetermined value, if the overheat rate of the coolant inputted into the compressor 2 is set to nil, and calories corresponding to the overheat rate is heated with the coolant being flowed into the third heat exchanger 60 during the warming operation, the COP can be improved.

By determining whether the overheat rate of the coolant inputted into the compressor 2 during the warming operation is needed to be set at the predetermined value, only when the overheat rate is needed to be set at the predetermined value, during the warming operation, the coolant may be flowed into the third heat exchanger 60.

[0104]

In the configuration of this Embodiment 15, during the cooling operation, it is also effective that, by suitably controlling the heat-exchanging amount in the coolant cooling means, using the heat-exchanging control means, the COP can surely be improved. It is also effective that, even if usage of the second coolant that is flammable or its global warming potential is inferior to that of the first coolant is

1 decreased, the COP equivalent to that of a case in which only the second coolant is

2 used can be realized. The coolant circuit of the second coolant can be configured by a

3 closed loop outside a room; thereby, leakage of the second coolant inside the room can

4 be prevented.

5 Moreover, it is also effective that the COP can be improved during the

6 warming operation.

7 Furthermore, it is effective that, by providing the third heat exchanger 60, the

8 COP can be more improved than that in a case in which the third heat exchanger 60 is

9 not provided.

10 [0105]

11 If the third radiator 50 is additionally provided, similarly to Embodiment 11,

12 in a case in which the temperature of the coolant outputted from the compressor 2 is

13 higher than that of the outdoor air, it is effective that the COP can be more improved

14 than that in a case in which the third radiator 50 is not provided. When the third

15 radiator 50 is also provided, the third radiator 50 is additionally provided between the

16 third heat exchanger 60 and the flow-route switching valve 52 so that the coolant does

17 not flow in the third radiator 50 during the warming operation.

18

19 [0106]

20 Embodiment 16.

21 In Fig. 24, a coolant-circuit diagram is illustrated for explaining a

22 configuration of an air conditioner having cooling and warming functions according to

23 Embodiment 16 of the present invention. In Embodiment 16, Embodiment 15 is

24 modified so that the coolant flows in parallel through the third heat exchanger 60 and

25 the second heat exchanger 13. Only different elements from those in Fig. 23

26 according to Embodiment 15 are explained.

27 In Fig. 24, the second bypass pipe 70 for introducing the second coolant into

28 the third heat exchanger 60, and the forth flow control valve 71 for regulating the flow

29 volume of the second coolant flowing in the third heat exchanger 60 are additionally

30 provided. Both of the forth flow control valve 71 and the second flow control valve 12

1   are arranged so as to flow in parallel the coolant outputted from the condenser 11.

2   The second coolant flows through the forth flow control valve 71, the second bypass

3   pipe 70, the third heat exchanger 60, and the second compressor 10, in that sequence.

4   The flow-route switching valve 52 for flowing, only during a cooling operation,

5   the coolant into the third heat exchanger 60 is not provided.

6   The other configurations are the same as those in Embodiment 15.

7   [0107]

8   Next, an operation is explained. During a cooling operation, the variation of

9   the coolant state in an air conditioner according to Embodiment 16 of the present

10   invention becomes, similarly to Embodiment 15, approximately the same as that in

11   Fig. 16 according to Embodiment 9.

12   During a warming operation, the forth flow control valve 71 is controlled so as

13   not to flow the second coolant into the third heat exchanger 60, and the second flow

14   control valve 12 is controlled similarly to Embodiment 3. During the warming

15   operation, the variation of the coolant state becomes, similarly to Embodiment 15, the

16   same as that in Fig. 8 according to Embodiment 3.

17   [0108]

18   This Embodiment 16 also has the same effect as that in Embodiment 15,

19   because the variation of the coolant states is the same.

20   Moreover, because the forth flow control valve 71 is provided, the flow volume

21   of the second coolant flowing in the third heat exchanger 60 can be independently

22   controlled from the flow volume of the second coolant flowing in the second heat

23   exchanger 13; therefore, it is effective that the operational condition in which the COP

24   becomes the maximum is easy to be realized. Furthermore, during the warming

25   operation, because the second coolant is not flowed in the third heat exchanger 60

26   using the forth flow control valve 71, the heat-exchanging amount can be set at nil;

27   therefore, it is effective that the flow-route switching valve 52 that is needed in

28   Embodiment 15 is not needed.

29   [0109]

30   If the third radiator 50 is additionally provided, similarly to Embodiment 11,

- 53 -

1 in a case in which the temperature of the coolant outputted from the compressor 2 is

2 higher than that of the outdoor air, it is effective that the COP can be more improved

3 than that in a case in which the third radiator 50 is not provided. In a case in which

4 the third radiator 50 is additionally provided, the flow-route switching valve 52

5 operating so that the coolant does not flow in the third radiator 50 during the warming

6 operation is also additionally provided.

7

8 [0110]

9 Embodiment 17.

10 In Fig. 25, a coolant-circuit diagram is illustrated for explaining a

11 configuration of an air conditioner having cooling and warming functions according to

12 Embodiment 17 of the present invention. In Embodiment 17, Embodiment 16 is

13 modified so that the third radiator 50 is provided. Only different elements from those

14 in Fig. 24 according to Embodiment 16 are explained.

15 In Fig. 25, the third radiator 50, and the flow-route switching valve 52 as a

16 flow-route switching means for inputting the coolant into the third heat exchanger 60

17 without flowing it in the third radiator 50 during a warming operation are additionally

18 provided.

19 The flow-route switching valve 52 is installed between the compressor 2 and

20 the third radiator 50. In the flow-route switching valve 52, the coolant can flow either

21 through the coolant pipe 6A for introducing the coolant into the third radiator 50 or

22 through the coolant pipe 6B connected to the coolant pipe 6 that connects the third

23 radiator 50 with the third heat exchanger 60.

24 The other configurations are the same as those in Embodiment 16.

25 [0111]

26 Next, an operation is explained. During a cooling operation, the variation of

27 the coolant states in the air conditioner according to Embodiment 17 of the present

28 invention becomes the same as that in Fig. 18 according to Embodiment 11.

29 During a warming operation, the forth flow control valve 71 is controlled so as

30 not to flow the second coolant into the third heat exchanger 60, and the second flow

1 control valve 12 is controlled similarly to Embodiment 3. The variation of the coolant

2 states during the warming operation becomes, similarly to Embodiment 16, the same

3 as that in Fig. 8 according to Embodiment 3.

4 [0112]

5 In this Embodiment 17, in addition to the effect in Embodiment 16, it is

6 effective that, by providing the third radiator 50, the COP can be more improved than

7 that in a case in which the third radiator 50 is not provided.

8 Although, in this Embodiment 17, the coolant is flowed into the third heat

9 exchanger 60 during the warming operation, even though it is configured such that

10 the coolant is not flowed, the same effect is obtained.